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APPLICATION OF SPLIT FLOW DESIGN TECHNIQUE TO SIMPLE MICROCHANNEL GEOMETRIES FOR ENHANCED MIXING

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ABSTRACT

The ability to control mixing of reagents in MEMS systems is crucial for many biological and chemical analysis applications. However mixing in these microfluidic devices is a challenge because the flows are laminar corresponding to very low Reynolds number.

In this paper mixing of such reagents in simple microchannel geometries is investigated computationally. A novel concept of "split flow design" is applied to these simple microchannel configurations. Significant improvement in mixing is seen by employing the split flow design technique.

INTRODUCTION

Bhopte et al. [1] have computationally investigated mixing of reagents in a "T" shaped microchannel. The channel branches are 200 µm wide and 120 µm deep, which is a typical scale for mass produced disposable devices. Similar aqueous solution enters through the two inlets with a velocity of 1 mm/s, diffusion constant of 10^{-10} m^2/s and kinematic viscosity of 10^{-6} m^2/s, typical properties for small proteins in aqueous solutions [2-6]. Only mixing of two components is treated here, other effects such as chemical reactions are not included.

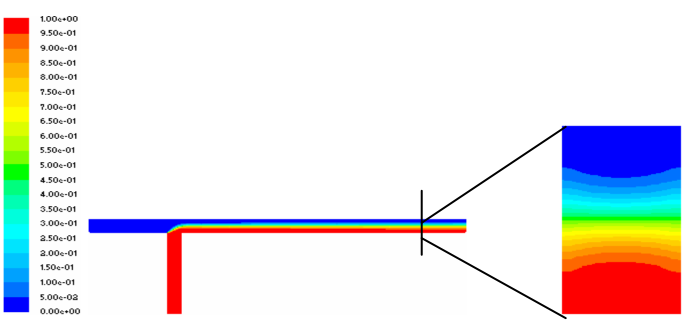


Figure 1: Mass fraction contours in a "T" shaped microchannel

Figure 1 shows mass fraction contours in a "T" shaped microchannel. Fluid "A" has mass fraction, $c = 0$ and is shown in blue and Fluid "B" is shown in red corresponding to $c = 1$. Hence mass fractions of 0 and 1 comprise the inlet flow regions. A green color corresponds to a mass fraction of 0.5 indicating a uniformly mixed fluid region. To calculate degree of mixing (DOM) we use the method discussed by Glasgow et al [2]. Mass fraction of liquid "B" (x_i) is monitored at the center of each cell at a cross-section 500 µm behind the outlet of the microchannel.

$$DOM = 1 - \frac{1}{\mu}\sqrt{\sum_{i=1}^{n}\frac{(x_i-\mu)^2}{n}\frac{v_i}{v_{mean}}} \qquad (1)$$

Equation 1 is used to calculate DOM, where v_i is the velocity in the i^{th} cell, v_{mean} is the mean velocity at the cross-section considered, x_i is the mass fraction of fluid B in i^{th} cell, n is the number of cells and μ=0.5 which is the targeted case of equal mixing of the two reagents. Equation 1 calculates mixing from 0 (no mixing) to 1 (complete mixing). Degree of mixing for the "T" shaped microchannel is calculated equal to 0.23.

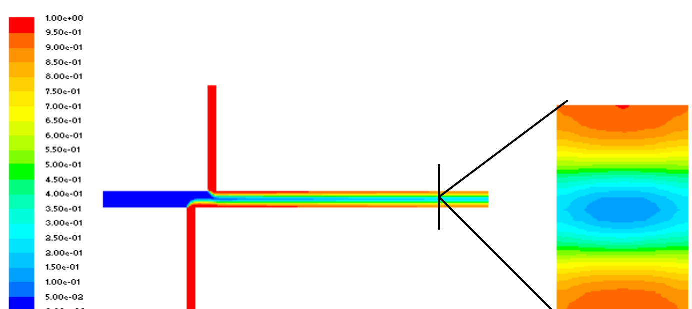
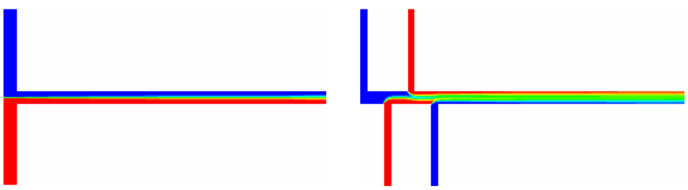


Figure 2: Two way split flow design applied to "T" shaped microchannel.

Figure 2 shows a two-way split flow design applied to "┬" shaped microchannel. Two-way split flow technique is a geometric modification to "┬" microchannel and is done by splitting the perpendicular inlet such that its flow rate is halved. This is achieved by making the cross-section 100 µm wide (instead of 200 µm) and 120 µm deep. An additional inlet of the same dimension impinges the lateral flow from opposite direction. Significant improvement in mixing is seen because of creation of an additional fluid A – fluid B interface and generation of transverse velocity at two locations.

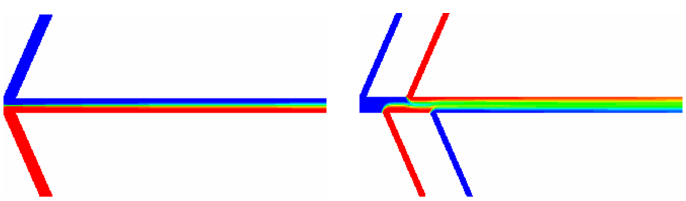
APPLICATION OF SPLIT FLOW DESIGN TO SIMPLE MICROCHANNEL GEOMETRIES

In this section split flow design technique is applied to simple microchannel geometries. All the geometries initially have two inlets and one outlet. Both the inlets are split (resulting in 4 inlets) and the halved flow rates are imposed over the lateral flow from two opposite directions. Mass fraction contours clearly show enhanced mixing (green contours) for all the corresponding split flow designs (refer to figures 3, 4 & 5).



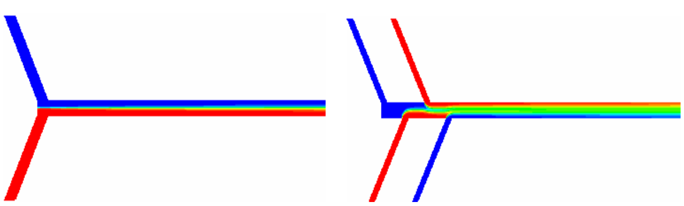
(a) (b)

Figure 3: Mass fraction contours for (a) ├ microchannel (b) two-way split flow design applied to ├ microchannel.



(a) (b)

Figure 4: Mass fraction contours for (a) ← microchannel (b) two-way split flow design applied to ← microchannel.



(a) (b)

Figure 5: Mass fraction contours for (a) Y microchannel (b) two-way split flow design applied to Y microchannel.

CONCLUSIONS

For all the three configurations viz. "├", "←" and "Y" shaped microchannels; application of split flow design technique is shown to improve the mixing significantly. This improvement is due to creation of multiple fluid A – fluid B interfaces over the same cross-section and generation of transverse velocities in lateral flow at 4 locations. Figure 6 shows a comparison of all the three designs considered with the corresponding split flow design modifications. For all the cases approximately 300% improvement in mixing is achieved by employing this simple geometric modification technique.

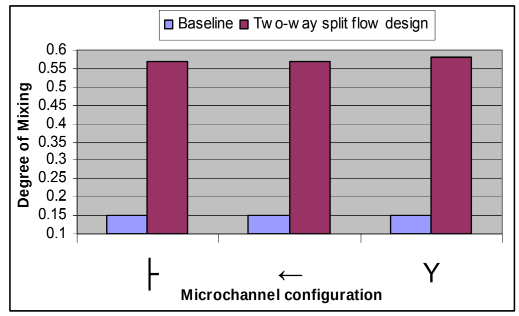


Figure 6: Comparison of "├", "←" and "Y" designs with their corresponding split flow design modifications.

REFERENCES

[1] Bhopte S., Sammakia B. and Murray B., "Mixing in a two component microchannel flow – geometric and pulsed flow effects", IMECE2007-43387, Proceedings of IMECE 2007, November 11-15 2007, Seattle, Washington.
[2] Glasgow I., Lieber S. and Aubry N., "Parameters Influencing Pulsed Flow Mixing in Microchannels", Analytical Chemistry, Vol. 76, pp. 4825-4832, August 15, 2004.
[3] Glasgow I. and Aubry N., "Mixing Enhancement in Simple Geometry Microchannels", IMECE2003-41586, Proceedings of IMECE 2003, Washington D.C., November 15-21, 2003.
[4] Goullet A., Glasgow I. and Aubry N., "Effects of Microchannel Geometry on Pulsed Flow Mixing", Mechanics Research Communication 33 (2006), pp. 739-746
[5] Goullet A., Glasgow I. and Aubry N., "Dynamics of Microfluidic Mixing Using Time Pulsing", Discrete and Continuous Dynamical Systems, Supplement Volume 2005, pp. 327-336.
[6] Glasgow I. and Aubry N., "Enhancement of Microfluidic Mixing Using Time Pulsing", Lab Chip, 2003, 3, pp. 114-120.
[7] Johnson T.J., Ross D., Gaitan M. and Locascio L.E., "Microfluidic Passive Mixing Structures", National Institute of Standards and Technology.
[8] Dasgupta P.K., Surowiec K. and Berg Jordan, "Flow of Multiple Fluids in a Small Dimension", Analytical Chemistry, April 1, 2002, Volume 74, Issue 7, pp. 208 A – 213 A.
[9] Fluent 6.2.16 User Manual

